Cryogenic Insulation Standard Data and Methodologies (CTIS)

Completed Technology Project (2013 - 2014)

Project Introduction

Extending some recent developments in the area of technical consensus standards for cryogenic thermal insulation systems, a preliminary Inter-Laboratory Study of foam insulation materials was performed by NASA Kennedy Space Center and LeTourneau University. The initial focus was ambient pressure cryogenic boil off testing using the Cryostat-400 flat-plate instrument. Completion of a test facility at LETU has enabled direct, comparative testing, using identical cryostat instruments and methods, and the production of standard thermal data sets for a number of materials under sub-ambient conditions. The two sets of measurements were analyzed and indicate there is reasonable agreement between the two laboratories.Based on cryogenic boiloff calorimetry, new equipment and methods for testing thermal insulation systems have been successfully developed. These boiloff instruments (or cryostats) include both flat plate and cylindrical models and are applicable to a wide range of different materials under a wide range of test conditions. Test measurements are generally made at large temperature difference (boundary temperatures of 293 K and 78 K are typical) and include the full vacuum pressure range. Results are generally reported in effective thermal conductivity (k_e) and mean heat flux (q) through the insulation system. The new cryostat instruments provide an effective and reliable way to characterize the thermal performance of materials under sub-ambient conditions. Proven in through thousands of tests of hundreds of material systems, they have supported a wide range of aerospace, industry, and research projects. Boiloff testing technology is not just for cryogenic testing but is a cost-effective, field-representative methodology to test any material or system for applications at sub-ambient temperatures. This technology, when adequately coupled with a technical standards basis, can provide a cost-effective, field-representative methodology to test any material or system for applications at sub-ambient to cryogenic temperatures. A growing need for energy efficiency and cryogenic applications is creating a worldwide demand for improved thermal insulation systems for low temperatures. The need for thermal characterization of these systems and materials raises a corresponding need for insulation test standards and thermal data targeted for cryogenic-vacuum applications. Such standards have a strong correlation to energy, transportation, and environment and the advancement of new materials technologies in these areas. In conjunction with this project, two new standards on cryogenic insulation were recently published by ASTM International: C1774 and C740. Following the requirements of NPR 7120.10, *Technical Standards for NASA Programs and Projects*, the appropriate information in this report can be provided to the NASA Chief Engineer as input for NASA's annual report to NIST, as required by OMB Circular No. A-119, describing NASA's use of voluntary consensus standards and participation in the development of voluntary consensus standards and bodies.

Although some standards exist for thermal insulation, few address the sub-ambient temperature range and cold-side temperatures below 100 K.

Cryogenic Insulation Standard Data and Methodologies

Table of Contents

Cryogenic Insulation Standard Data and Methodologies (CTIS)

Completed Technology Project (2013 - 2014)

Standards for cryogenic insulation systems require cryostat testing and data analysis that will allow the development of the tools needed by design engineers and thermal analysts for the design of practical cryogenic systems. Thus, this critically important information can provide reliable data and methodologies for industrial efficiency and energy conservation.

The needs for technical standards for thermal insulation systems are growing in the US and worldwide. Energy efficiency and conservation needs -- of which thermal insulation systems are a key part -- are a top priority for economic, national security, and technological concerns. The emphasis on technical consensus standards is a clear directive from both government policy and market economic drivers.

Summarized here are the most recent and relevant government policy directives to encourage technical standards development and energy efficiency technology implementation. The reference federal agency is NASA and the target subject area is thermal insulation systems for low-temperature applications. Here is a list of the relevant documents:

1. OMB Circular No. A-119, *Federal Participation in the Development and Use of Voluntary Consensus Standards and in Conformity Assessment Activities*.
2. *Memorandum for the Heads of Executive Departments and Agencies*, document M-12-08 dated January 17, 2012.
3. NPR 7120.10, *Technical Standards for NASA Programs and Projects*, Effective Date: April 22, 2011.

On February 4, 2011, the President released *A Strategy for American Innovation: Securing Our Economic Growth and Prosperity* and directed Federal agencies to increase their efforts to catalyze technology breakthroughs to advance national priorities. Pursuant to the Strategy for American Innovation, the Office of Science and Technology Policy (OSTP), the Office of Management and Budget (OMB), and the Office of the United States Trade Representative (USTR) are the *Memorandum for the Heads of Executive Departments and Agencies* was issued to clarify principles guiding Federal Government engagement in standards activities that can help address national priorities.

This R&D project was formulated in response to these agency and national objectives for technical standards. A preliminary Inter-Laboratory Study of foam insulation materials was conducted by NASA Kennedy Space Center (KSC) and LeTourneau University (LETU). The initial focus was ambient pressure (no vacuum) cryogenic boil off testing using two identical Cryostat-400 flat-plate instruments. Completion of a new test facility at LETU has enabled comparative testing, using similar methods, and the production of standard thermal data sets for cellular glass insulation material under cryogenic conditions. Test measurements were made at both KSC and LETU

Organizational Responsibility

Responsible Mission Directorate:

Mission Support Directorate (MSD)

Lead Center / Facility:

Kennedy Space Center (KSC)

Responsible Program:

Center Independent Research & Development: KSC IRAD

Project Management

Program Manager:

Barbara L Brown

Project Manager:

Pamela A Mullenix

Principal Investigator:

James E Fesmire

Co-Investigator:

Adam M Swanger

for comparative analysis. The results show reasonable agreement between the two laboratories. These initial measurements were made at the approximate boundary temperatures of 293 K and 78 K, the results of which are reported in comparative effective thermal conductivity (comparative k_e) and mean heat flux (q).

The main challenge is the production of standardized thermal data sets for cryogenic insulation materials and systems. This project took up the challenge and made progress in three ways. The first was to produce a cataloged set of reference test specimens of cellular glass material. Other materials have been identified for future reference test specimens. Second was to conduct a preliminary interlaboratory study of the cellular glass material using the same equipment and methods (Cryostat-400 instrument). The third way was to show the practicality of using boiloff calorimetry to obtain thermal data for stack-ups of different materials (composite panels and insulation materials alike). The boiloff method, being a direct measure of heat energy, provides effective test solutions where other existing commercial methods fall short or are not possible.

In conjunction with this project, two new standards on cryogenic insulation were recently published by ASTM International: C1774 and C740. Following the requirements of NPR 7120.10, *Technical Standards for NASA Programs and Projects*, the appropriate information in this report can be provided to the NASA Chief Engineer as input for NASA's annual report to NIST, as required by OMB Circular No. A-119, describing NASA's use of voluntary consensus standards and participation in the development of voluntary consensus standards and bodies. Further standards in the area of cryogenic insulation systems have been targeted for future development.

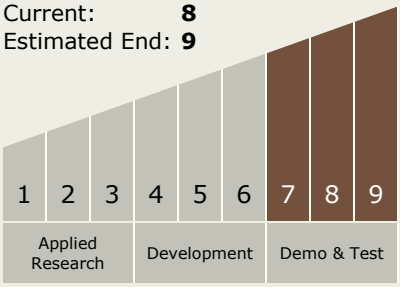
This project involved a number of tasks that were synergetic with other projects under Advanced Exploration Systems, Center Innovation Fund, Game Changing Technology, and others. Compliance issues associated with PVS systems requirements was a major hit on resources in 2013 thus making this leveraging among projects crucial for this work. Three New Technology Reports, three peer-reviewed publications, and one full patent application were also produced in conjunction with this project. Additonal publications and patents are pending.

Anticipated Benefits

To make cryogens more practical to store and transfer, whether on Earth or in space or other destinations, benchmark thermal performance data are needed. To obtain such data, standard approaches, methodologies, and apparatuses are also needed. This project addresses the problem in a three pronged approach: materials science and development; testing methodolgies and equipment. Programs and projects supported include, for example: SLS

Technology Maturity (TRL)

Start: **7**
Current: **8**
Estimated End: **9**



Technology Areas

Primary:

- TX14 Thermal Management Systems
  - TX14.1 Cryogenic Systems
    - TX14.1.4 Ground Testing & Operations

vehicle, Game Changing Technology - Cryogenic Composite Tanks, Advanced Exploration Systems - Liquid Hydrogen and Liquid Oxygen Ground Operations Demonstrations, SBIR - materials research projects (collaboration with companies), Cryogenic Spill Protection for LNG Cryofuel Systems, CIF - Multifunctional Structural Thermal Composites, NIAC - Lunar Regolith Regolith-Derived Heat Shield, etc.

This project is one part of a larger effort that has ensued since the completion of the NASA Internal Research and Development (IR&D) project *Technologies to Increase Reliability of Thermal Insulation Systems* funded by the Space Operations Mission Directorate (SOMD) in 2004.

The standard reference data sets produced are available for cryogenic systems design, analysis, and development. Future technical consensus standards are envisioned for both test methods and materials practices. Specific test methods would be formulated for cylindrical and flat plate geometries covering absolute and comparative approaches, as required by mutual industry needs. Standard data sets for specific materials would then be produced through a round robin of cryogenic testing among laboratories, thus enabling new standard material practices.

Existing information combined with the latest research test data has been organized to help solve the problems presented by the thermal environments of the Earth, launch ascent, Moon, and Mars. The Cryogenics Test Laboratory at NASA Kennedy Space Center has produced much new information on cryogenic and vacuum environments including high vacuum (Moon or Earth orbit), soft vacuum (Mars or launch ascent), and no vacuum (Earth atmosphere with or without humidity). The materials include multilayer insulation, aerogel blankets, aerogel bulk-fill, foams, composites, and many other constructions.

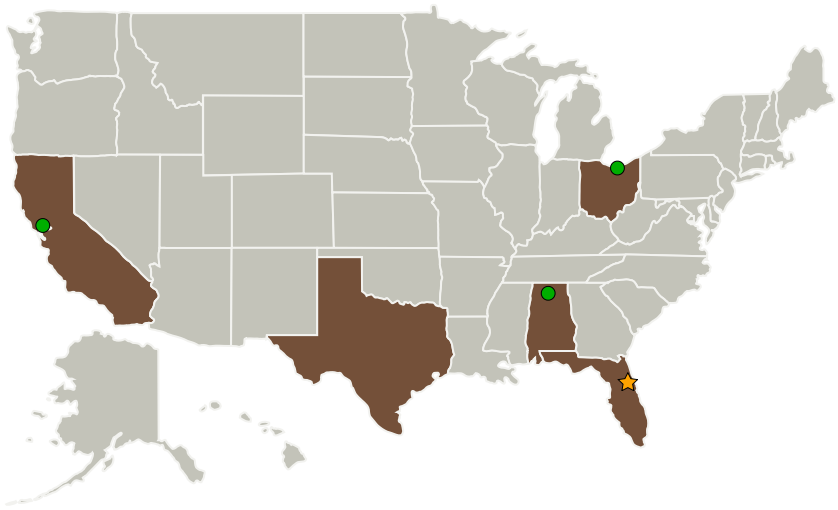
What is the point? New thermal materials and thermal management systems are needed for future space launch vehicles and the space exploration enterprise. This critical area of new technology is now in a competitive global launch market. Thermal insulation must be considered as an integrated system, not merely an add-on element. The end of insulation as a bolt-on element is the underlying theme of this R&D project. Development of thermal insulation systems technology should proceed from basic understanding of both high temperature and low temperature requirements (hot side + cold side) as well as structural and thermal requirements. To address the total energy efficiency picture of any complex space hardware system the development must also consider both active systems such as cryocoolers and passive systems such as foam materials. Multifunctional thermal insulation systems are a key to technological advancements that can be achieved by considering materials, testing, and engineered applications.

Energy use, efficiency, conservation, and alternatives are critical to the future on Earth and in space, only 10% of total usage has to do with electrical energy while 90% is thermal energy! To have basic information on low-temperature thermal insulation is an enabling and cross-cutting benefit for NASA and industrial needs nationwide and on a global scale. Cryogenic insulation requirements are spread throughout propulsion, airframe, architecture, and launch systems. Historically, programs have assumed others would cover this work or that the work would be covered by another related system area. The work is discipline advancing and the development of standards has the potential to benefit many programs and projects. The work addresses issues common to propulsion, life support, power, and science (refrigeration) systems, including flight, in-space, and surface systems. Project advances both NASA-wide requirements and National directives by developing standard data and testing for cryogenic insulation materials. Strategic partnerships ensure maximum benefit to NASA objectives for technology advancement, engineering information, and technical capabilities.

Cryogenic Insulation Standard Data and Methodologies (CTIS)

Completed Technology Project (2013 - 2014)

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
★Kennedy Space Center(KSC)	Lead Organization	NASA Center	Kennedy Space Center, Florida
●Ames Research Center(ARC)	Supporting Organization	NASA Center	Moffett Field, California
●Glenn Research Center(GRC)	Supporting Organization	NASA Center	Cleveland, Ohio
LeTourneau University	Supporting Organization	Academia	Longview, Texas
●Marshall Space Flight Center(MSFC)	Supporting Organization	NASA Center	Huntsville, Alabama

Cryogenic Insulation Standard Data and Methodologies (CTIS)

Completed Technology Project (2013 - 2014)

Co-Funding Partners	Type	Location
ASTM International(ASTM)	Industry	West Conshohocken, Pennsylvania
LeTourneau University	Academia	Longview, Texas
National Institute of Standards and Technology(NIST)	US Government	Boulder, Colorado
University of Central Florida(UCF)	Academia	Orlando, Florida

Primary U.S. Work Locations	
Alabama	California
Florida	Ohio
Texas	

Stories

Cryogenic insulation standard data and methodologies
(https://techport.nasa.gov/file/21728)

Cylindrical boiloff calorimeters for testing of thermal insulations
(https://techport.nasa.gov/file/21724)

Flat plate boiloff calorimeters for testing of thermal insulation systems
(https://techport.nasa.gov/file/21725)

Standardization in Cryogenic Insulation Systems Testing and Performance Data
(https://techport.nasa.gov/file/21729)

Links

ASTM C1774 - Standard Guide for Thermal Performance Testing of Cryogenic Insulation Systems
(http://www.astm.org/Standards/C1774.htm)

ASTM C740 - Standard Guide for Evacuated Reflective Insulation In Cryogenic Service
(http://www.astm.org/Standards/C740.htm)